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The Explosive Hazard of Incinerator Dust

Bureau of Solid Waste Management

1970

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Inherent in the nature of solid waste is a dust and dirt problem. An explosion at the Center Hill Incinerator, Cincinnati, Ohio, showed that incinerator dust was a problem. Although the recorded explosion damaged only property, another such explosion could result in injury or possibly loss of life. Therefore, the dust problem associated with incinerators took on a new dimension, and it was deemed important to study the explosibility of incinerator dust. The Bureau of Mines has conducted extensive research into dust explosions and the hazards associated with them. They have also developed the equipment to evaluate the explosibility of dusts and established the accepted standard in this field. The Bureau of Solid Waste Management developed an instrument similar to their Hartmann apparatus in order to evaluate the explosibility of incinerator dust.

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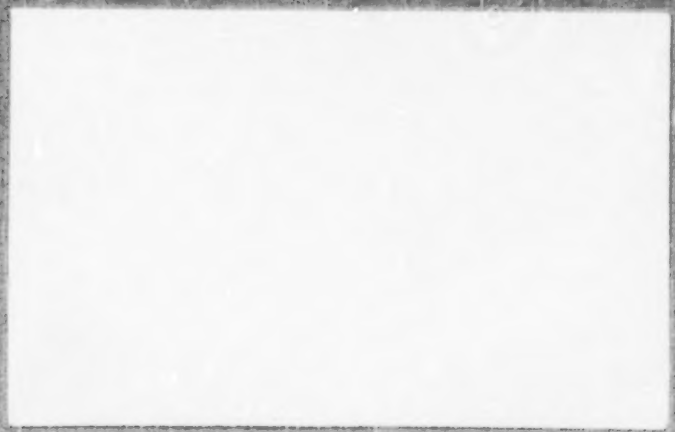

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THE EXPLOSIVE HAZARD

OF INCINERATOR DUST

A Division of Research and Development
Open-File Report (WP-02-69-24)

written by

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Solid Waste Management
1970

INTRODUCTION

Inherent in the nature of solid waste is a dust and dirt problem. Until recently, it was thought that inhaling the dust was the only health hazard associated with it. An explosion at the Center Hill Incinerator, Cincinnati, Ohio, showed that incinerator dust was harmful in another way. Although the recorded explosion damaged only property, another such explosion could result in injury or possibly loss of life. Therefore, the dust problem associated with incinerators took on a new dimension, and it was deemed important to study the explosibility of incinerator dust.

The Bureau of Mines has conducted extensive research into dust explosions and the hazards associated with them. They have also developed the equipment to evaluate the explosibility of dusts and established the accepted standard in this field. The Bureau of Solid Waste Management developed an instrument similar to their Hartmann apparatus in order to evaluate the explosibility of incinerator dust.

The author would like to thank Mr. John Nagy and his staff for all cooperation afforded to us during the course of the project.

Dust explosions are usually characterized by a well defined lower explosive limit and a less well defined upper limit. The primary goal of this research was to establish the lower explosive limit for incinerator dust.

The Bureau of Mines defines a dust explosion as: "A rapid combustion of a cloud of particulate matter in a confined or partially confined space where heat is generated at a higher rate than it is dissipated."[1] In conjunction with the heat development is a rapid increase in pressure inside the confined space. Generally, any combustible material in powdered form can produce a dust explosion when dispersed in air and ignited. For the explosion to occur, the source of ignition energy must be sufficiently intense to raise a portion of the cloud to its ignition temperature, and the dust concentration must be at least at the low limit or above. The combustion of the dust must generate enough energy to raise the neighboring dust to the ignition temperature. Thus, in a chain reaction effect, the flame front is propagated through the dispersed dust and an explosion is effected.

EXPERIMENTAL

The apparatus employed for these investigations was designed after the equipment used by the Bureau of Mines and patterned after the Hartmann apparatus.[2,3,4,5]

The Bureau of Solid Waste Management equipment consisted of a plexiglas tube 5-1/2 in. in diameter and 30 in. in length. The cylinder was supported on a 8"x8"x2 1/2" box which also housed the dispersion cup and air inlet. The dust is dispersed by a blast of compressed air that was stored in a 37.7 $in.^3$ reservoir under a pressure of 8.5 $lb/in.^2$ An electrode system was connected in series with a solenoid valve so that when the valve was opened, and the sample dispersed, energy was available for ignition.

All conditions, except the amount and type of dust being studied, were kept as constant as possible.

CALIBRATION

Dust explosions and the data obtained from them are unique due to the fact that one can ignite just about any concentration of dust by varying the physical parameters of the apparatus. For the collected data to have any meaning, they must be compared with a know quantity. Explosions were initiated in an actual coal mine and it was found that a coal dust concentration of 0.055 g/l was the minimum amount necessary for an explosion. This has been accepted as the standard and for any laboratory data to be valid, the instrument's minimum explosive concentration of coal dust must be 0.055 g/l.

Figures I through IV show four calibration curves for the apparatus employed. It can be seen from the graphs that some scattering of the data was found. This scattering led to poor correlation with a computer regression series, and therefore the average deviations were found and plotted. Figure V was the result of this plot, and the trend toward two areas - one explosion and the other nonexplosion - was observed. It is the feeling of the author that this phenomenon should be viewed as a minimum explosive concentration range rather than an absolute number. If this was the case, the calibration values would vary from 0.053 g/l to 0.057 g/l. The accepted value for calibration is 0.055 g/l, and the data presented fits this criteria.

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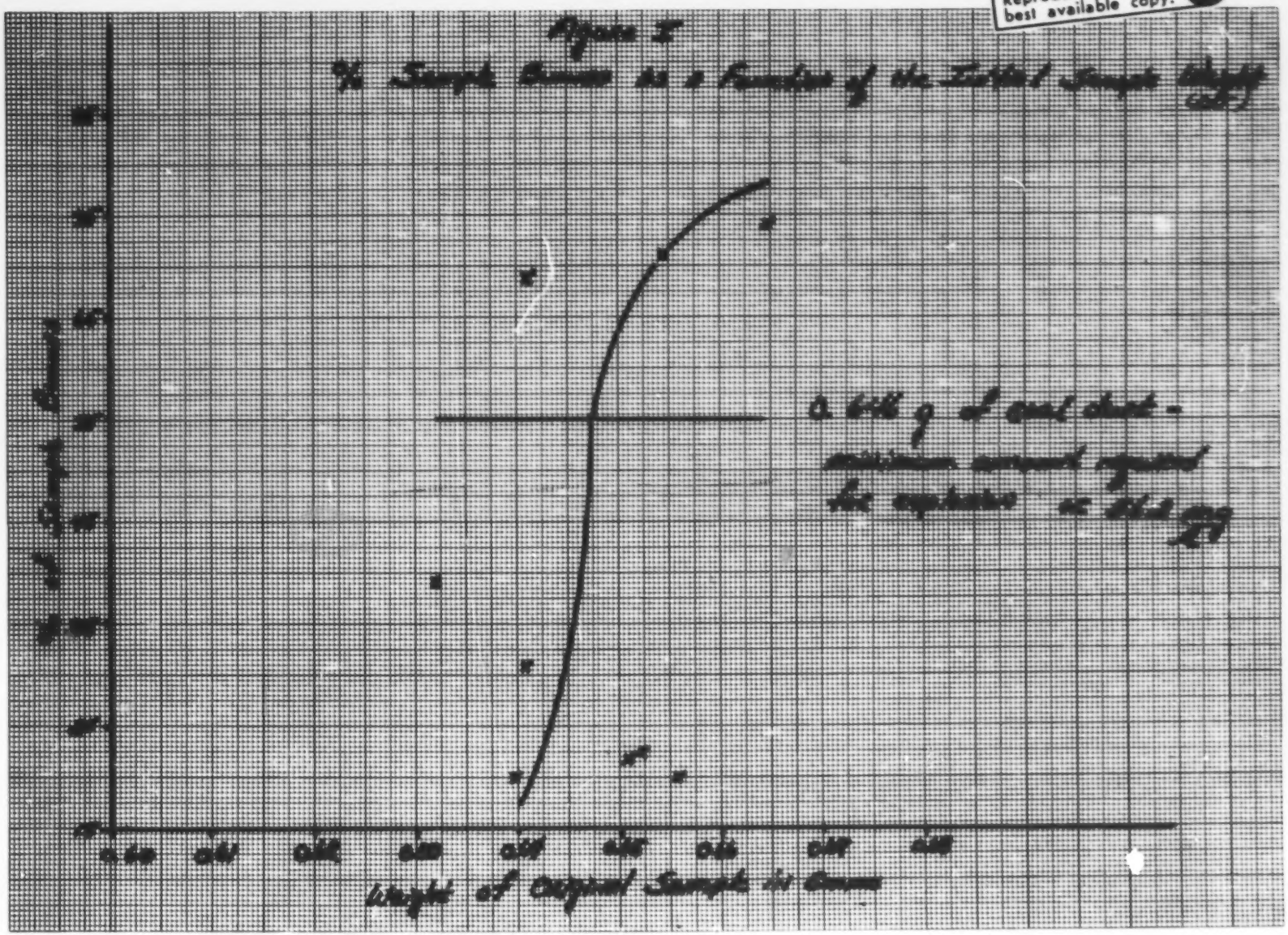


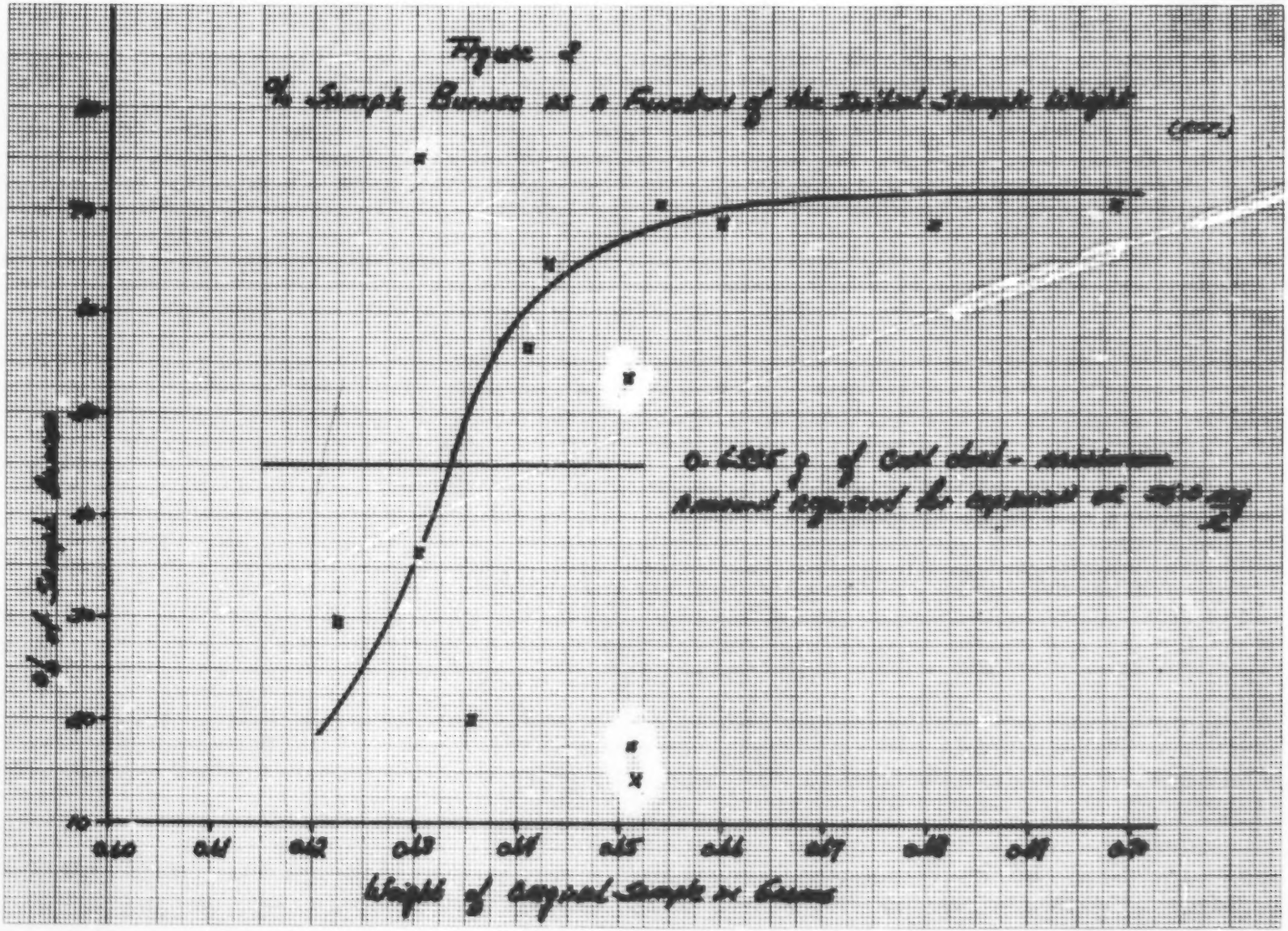


Figure 4
% Sample Burned as a Function of the Initial Sample Weight
0.4285 g of coal dust - maximum amount required for explosion at this energy
% of Sample Burned
Weight of Original Sample in Grams

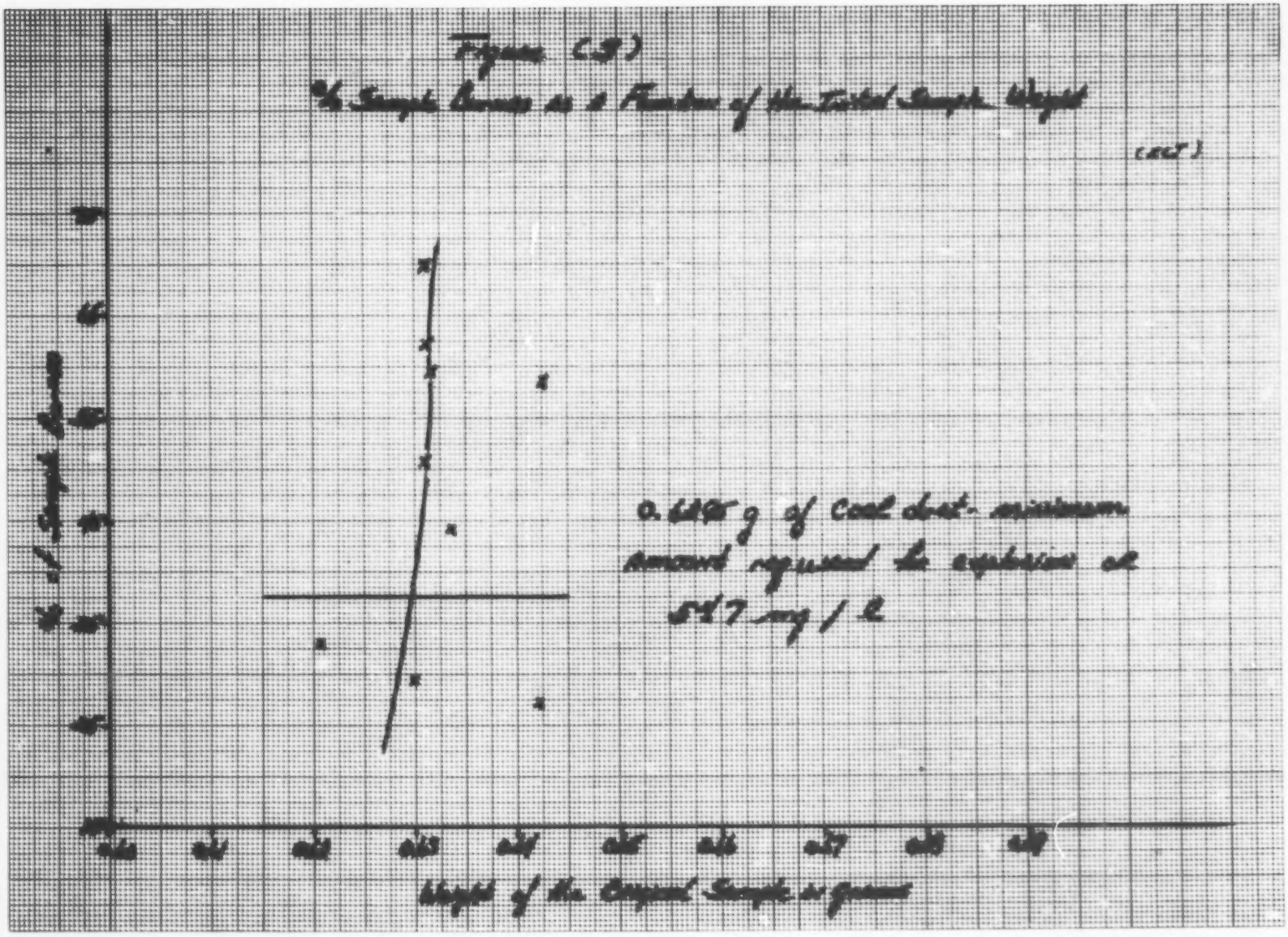


Figure (8)
% Sample Survival as a Function of the Initial Sample Weight
(wet)
0.450 g of coal dust- minimum
amount required to equivalent of
647 mg/l
Weight of the Original Sample in grams

Figure (4)

% Sample Burned as a Function of the Initial Sample Weight (AZT)

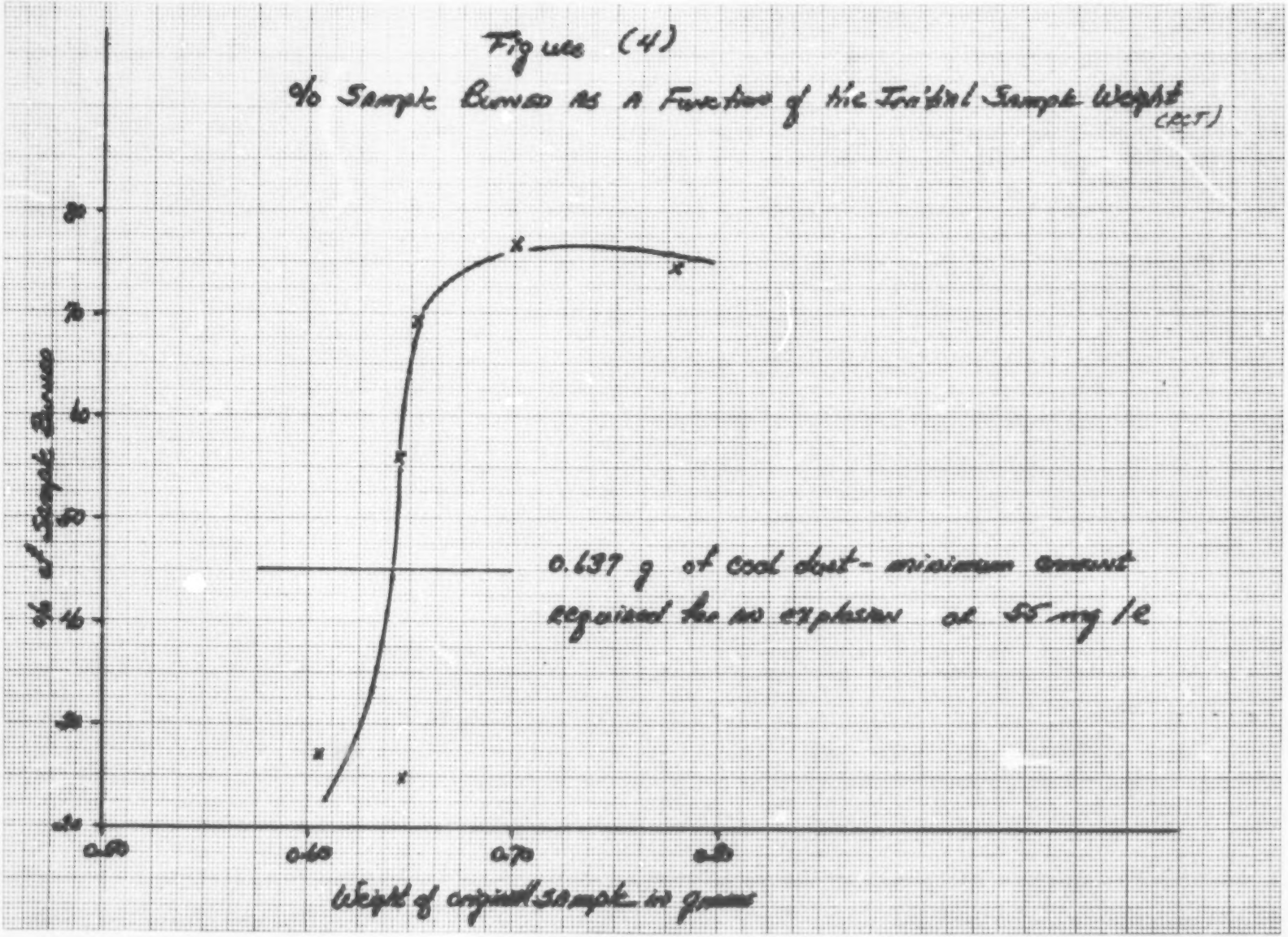
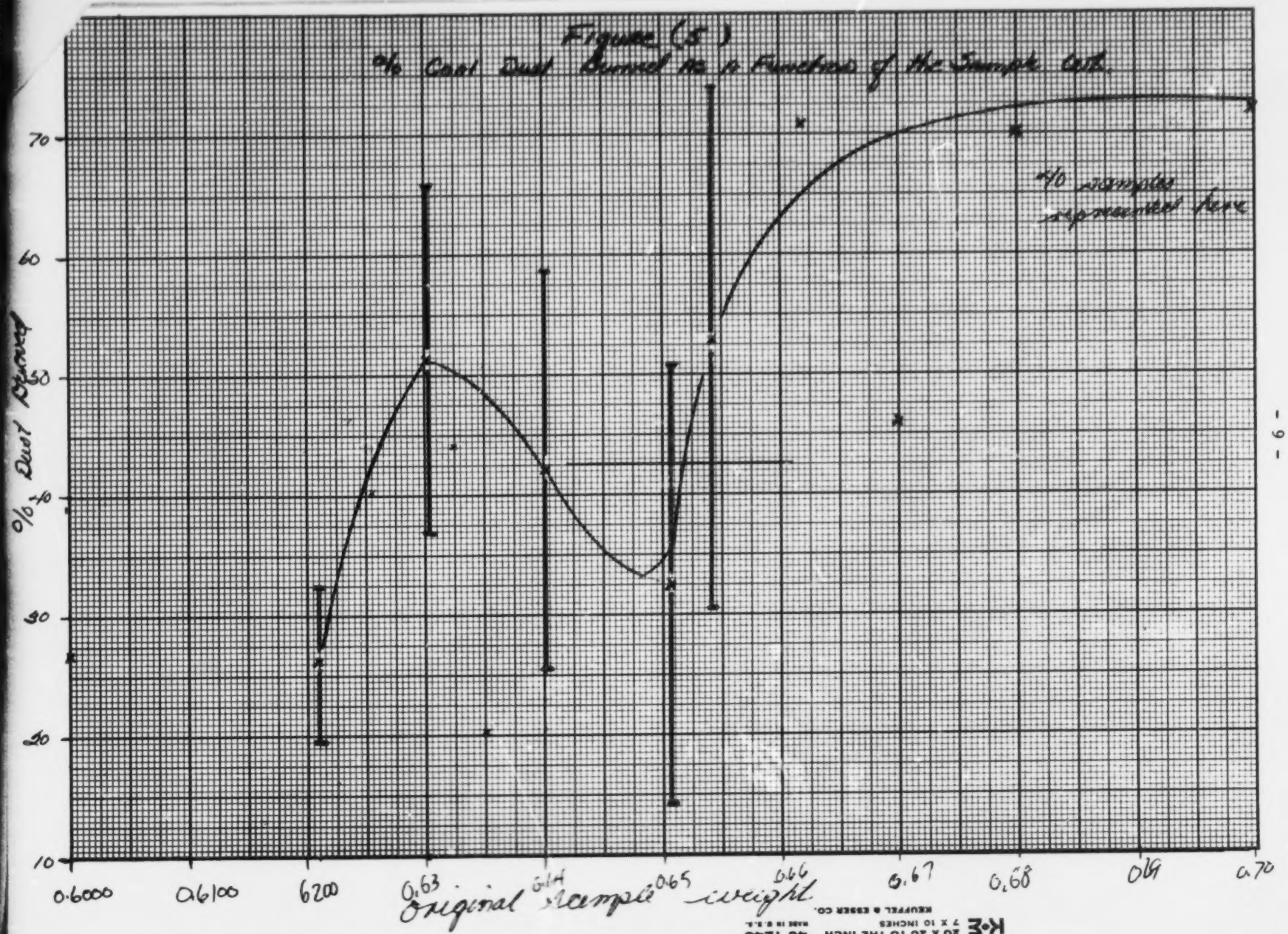

% of Sample Burned
Weight of original sample in grams
0.637 g of coal dust - minimum amount required for an explosion at 45 mg/l

Figure (5)

% Coal Dust Burned as a Function of the Sample wt.



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RESULTS

I. Incinerator Samples

A. Airborne Samples

Samples of airborne incinerator dust were collected at the Center Hill Incinerator, Cincinnati, Ohio, on three different dates.

Figures (6) through (8) show the amount of dust burned as a function of the initial sample weight. It was assumed that the amount of dust dispersed, and hence its concentration, was proportional to the sample burned in the same way as when the apparatus was calibrated with coal dust.

At no time during the experiments with the airborne samples was an explosion or combustion observed. The explosive index for incinerator dust ranged from <0.45 to <0.22.* The results were expressed in this manner (as an indication of a lower limit) because of the insufficient amount of dust available. Even though an exact number was not found for the index, it seems reasonable to say that is small enough to be considered a weak explosive hazard or no hazard at all.

B. Accumulated Samples

Samples of the dust that had accumulated throughout the incinerator over a period of time were also taken. It was reasoned that for dust to be found on the walls, railings, etc.,

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*Ratio of explosive severity to a standard.

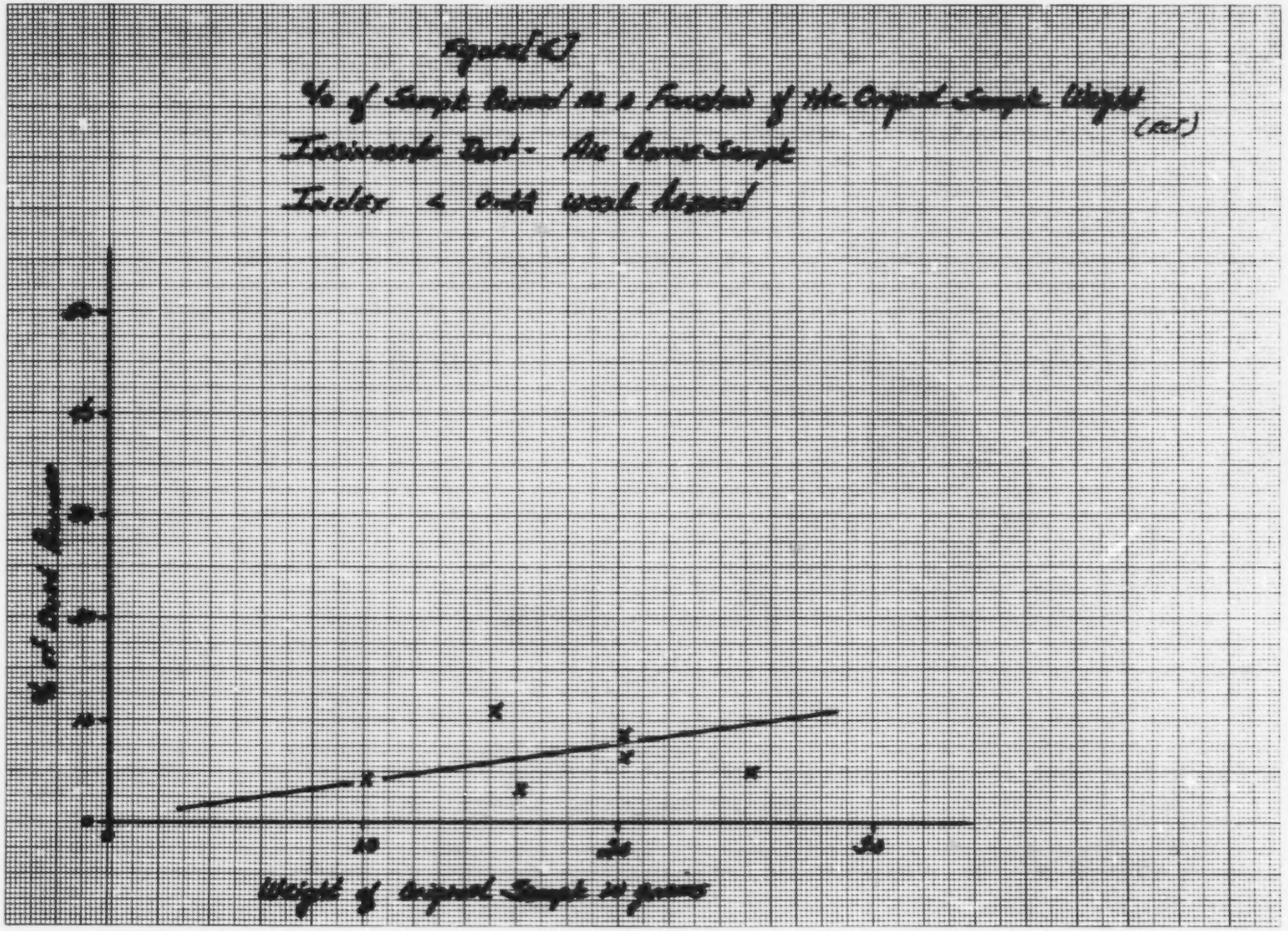


Figure [illegible]
% of Sample Burned as a Function of the Original Sample Weight (ref)
Incinerator Dust - Air Burner Sample
Index < cold wool Aspect
% of Sample Burned
Weight of Original Sample in grams

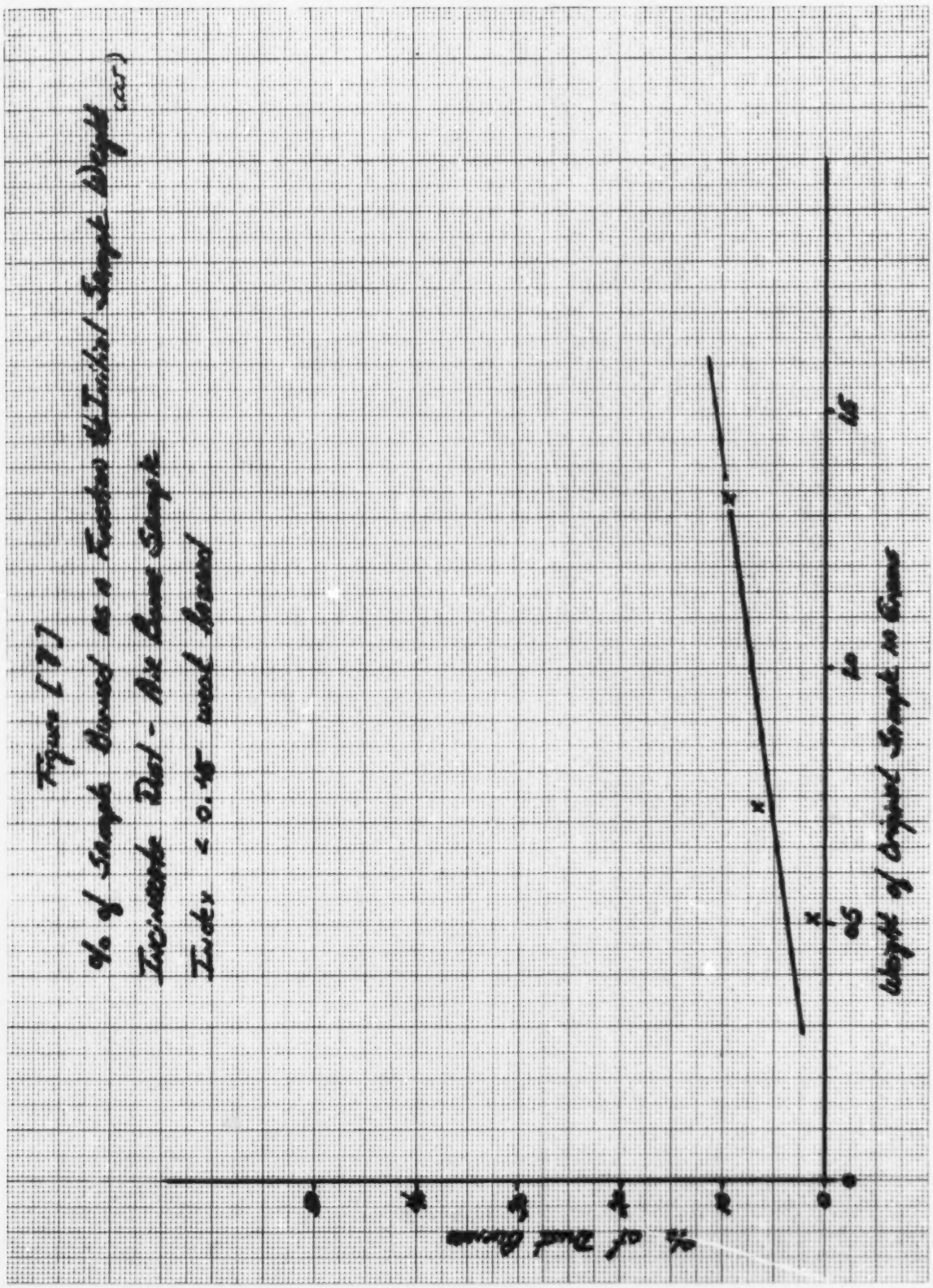
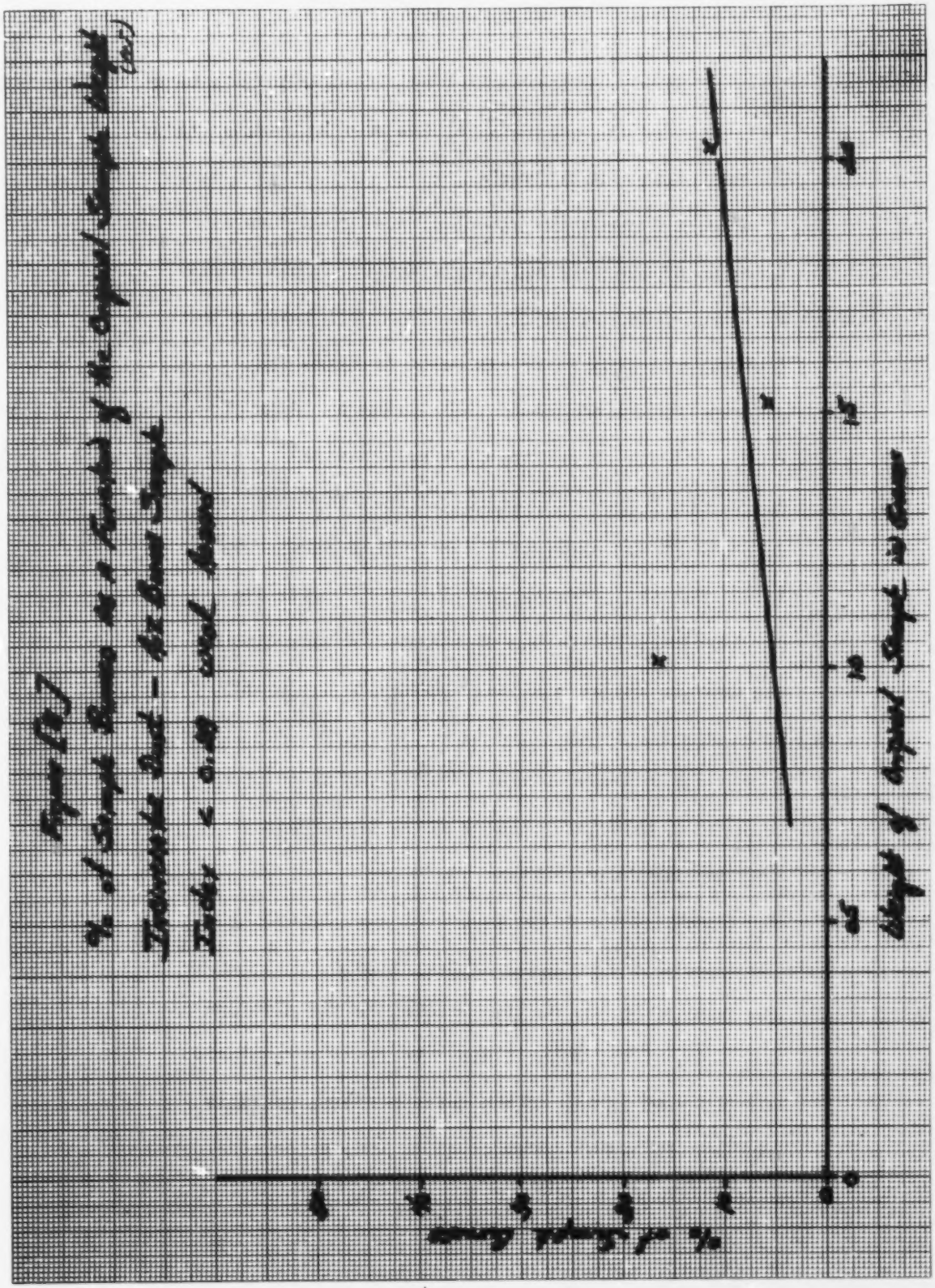


Figure (7)
% of Sample Blanked as a Function of BTU/lb of Sample Weight (as rec'd)
Zirconium Dust - Air Atmosphere
Zircon < 0.15 mm Material
% of Sample Blanked
Weight of Original Sample in Grams
0
40
80
120



the dust must have been airborne at one time, and would be a good indication of the condition of the dust at earlier times.

1. Incinerator Wall Sample

   Figure 8 shows the amount of dust burned as a function of the original sample weight. This sample was taken from the wall in the stairwell leading to the charging floor. No explosion or flame was observed in any of the tests. It had an index of <0.22, and can be considered a weak hazard.

2. Figure 9 shows the amount of dust burned as a function of the original weight. This sample was taken from the charging room floor. A small flame was observed, but it was not the rapid combustion as observed in the standard. Based on the observed data, the index was found to be 0.33. This in itself tends toward a weak hazard, and it is the opinion of this investigator that it presents no ordinary explosive hazard.

3. Figure 10 shows the amount of dust burned as a function of the original sample weight. This sample was taken from the railing leading to the platform on the right of the deposit dip. No flame or explosion was observed in any of the tests performed on this sample. It had an index of <0.28 and can be considered a weak hazard.

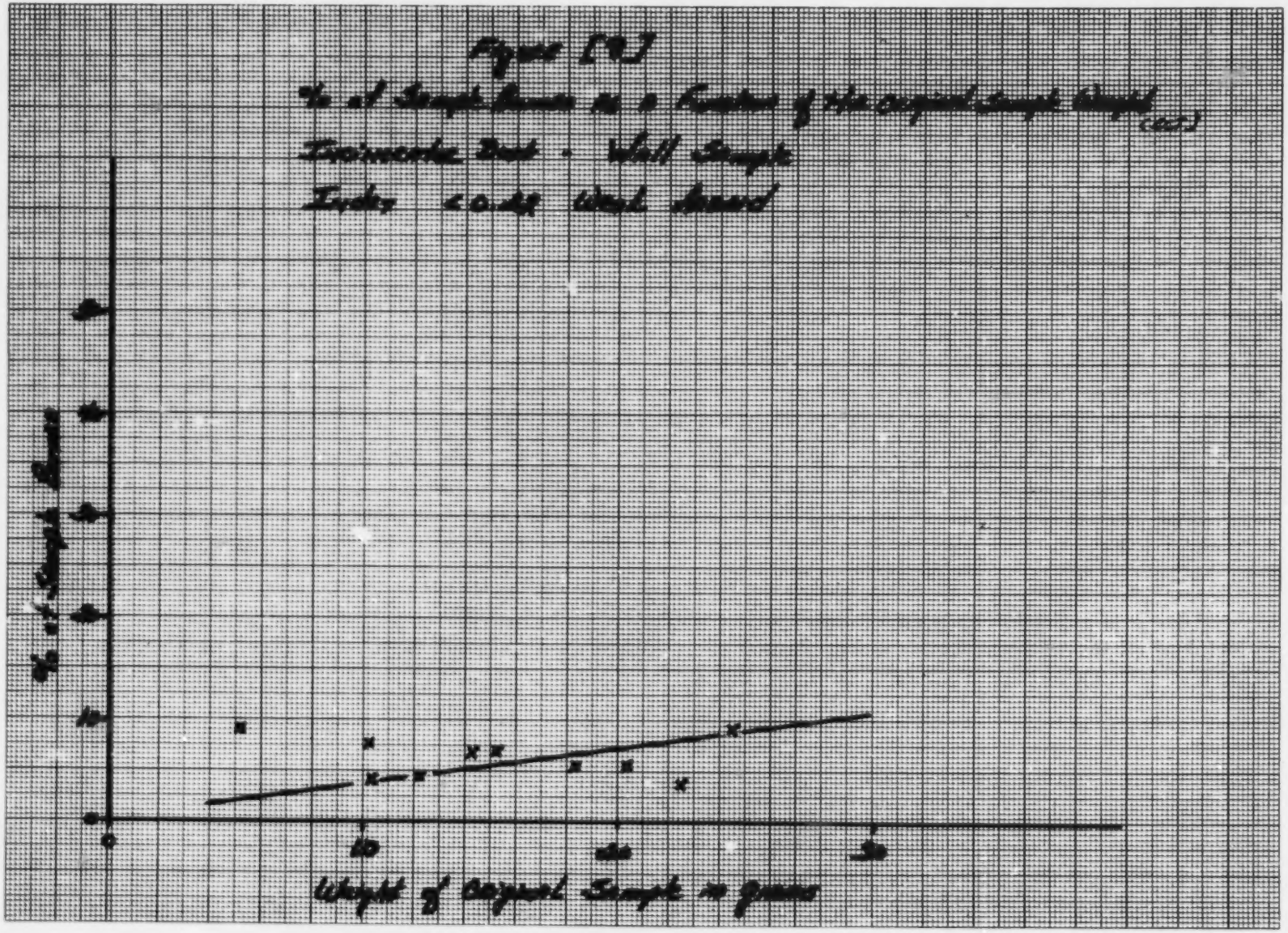


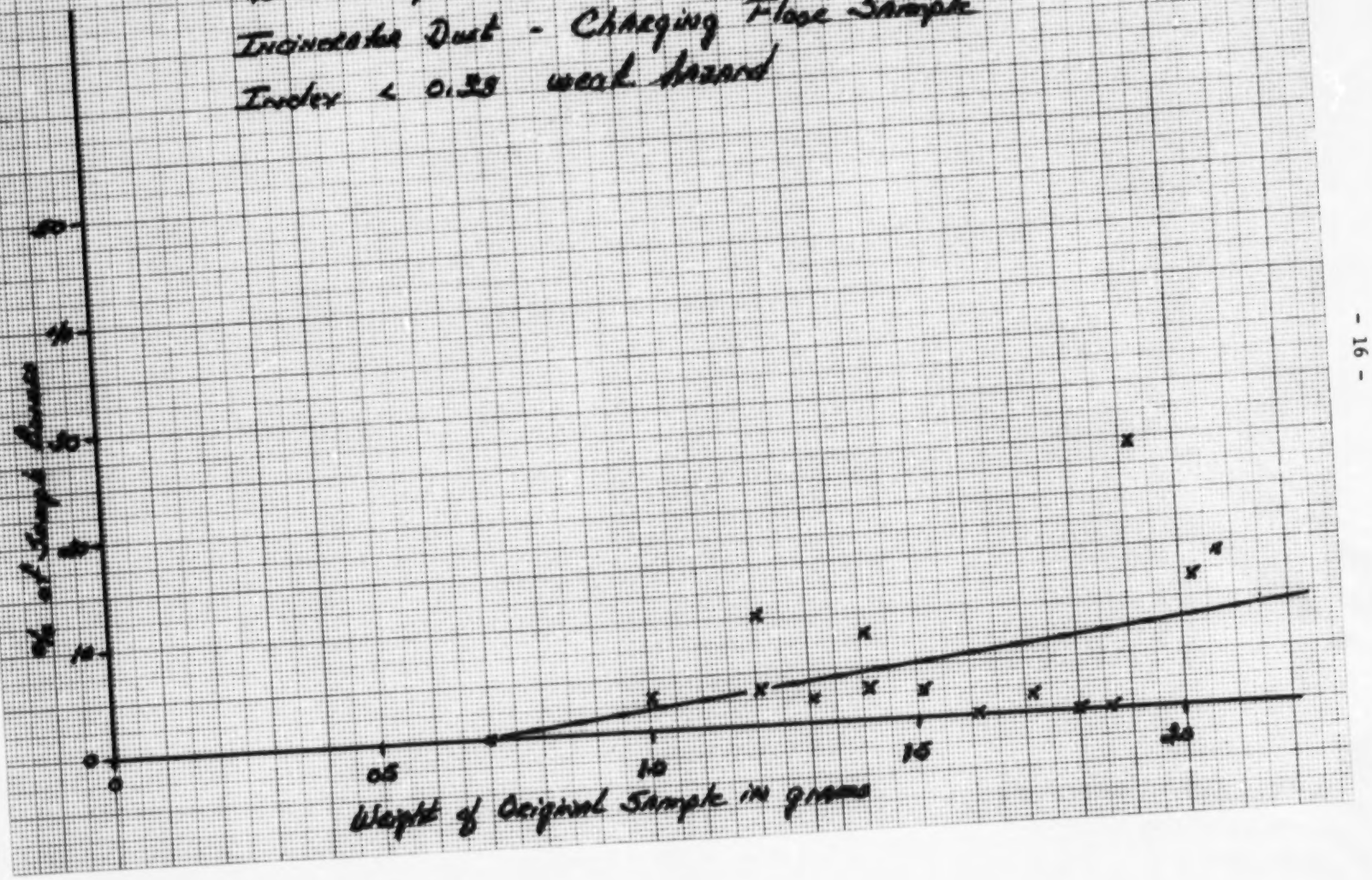
Figure [9]
% of Sample Mass as a Function of the original Sample Weight (gm)
Dolomite Dust - Mill Sample
Index Code Used Above
Weight of original Sample in grams

Figure [10]

% of Sample Burned as a Function of Original Sample Weight (ACT)

Incinerator Dust - Charging Floor Sample

Index < 0.29 weak hazard



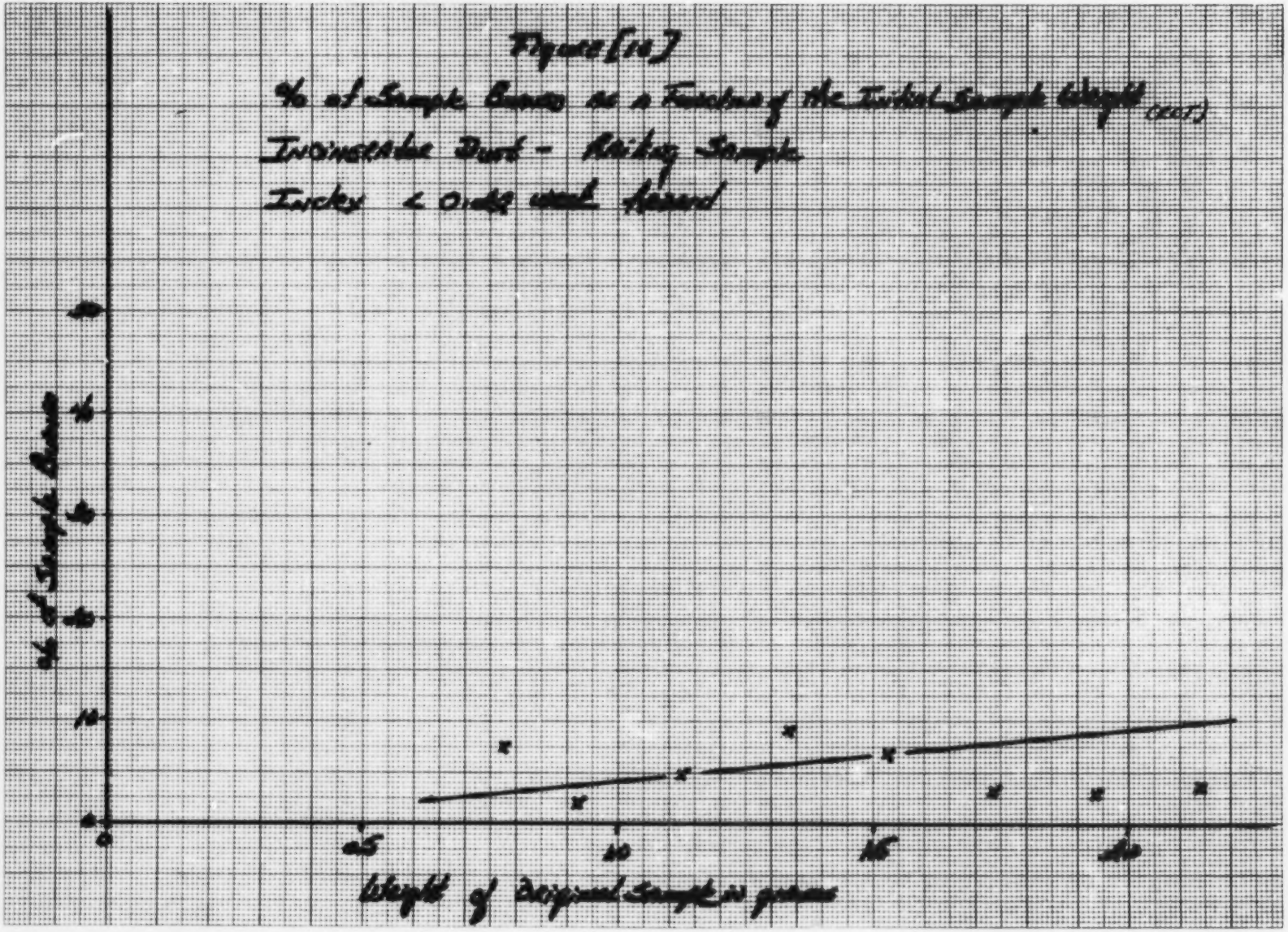


Figure [11]
% of Sample Passing as a Function of the Total Sample Weight (cont.)
Invisible Dust - Mixing Sample
Inches < 0.149 mm and Passed
% of Sample Passing
Weight of Original Sample in grams

4. Figure 11 shows the amount of dust burned as a function of the original sample weight. This sample was taken from the platform area to the right of the deposit pit. No flame or explosion was observed in any of the tests performed on this sample. It had an index of <0.25, and can be considered a weak hazard.

II. Ground Refuse Samples

In an effort to gain more insight into the problem of incinerator dust explosions or nonexplosions, ground refuse was worked up in a similar manner as the incinerator samples. It was ground, put through a 200 mesh screen, and dried at 70°C for 24 hours. Figures 12 and 13 show the amount of sample burned as a function of the original sample weight. Contrary to what was observed with incinerator dust, ground refuse showed a combustibility greater than the coal dust standard. The indices ranged from 1.4 to 1.8 indicating a hazard greater than the standard, and thus greater than a moderate hazard. Dust, related to grinding operations should, therefore, be treated as a potentially explosive hazard. Care should be taken to maintain low levels of refuse dust.

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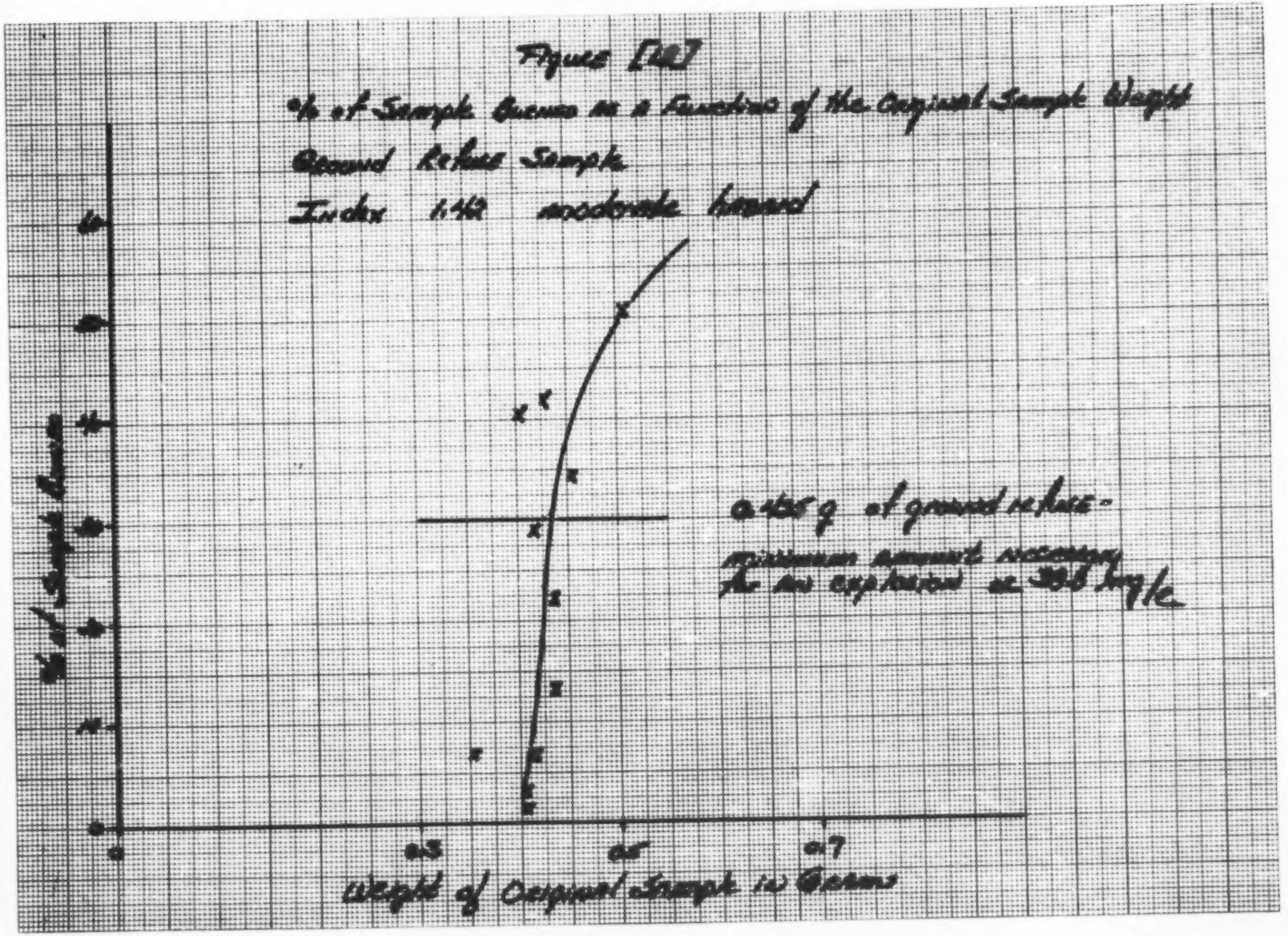
Figure [10]

% of Sample Passing as a Function of the Original Sample Weight

Ground Refuse Sample

Index 1.42 moderate hazard



0.105 g of ground refuse - minimum amount necessary for an explosion at 395 kg/c

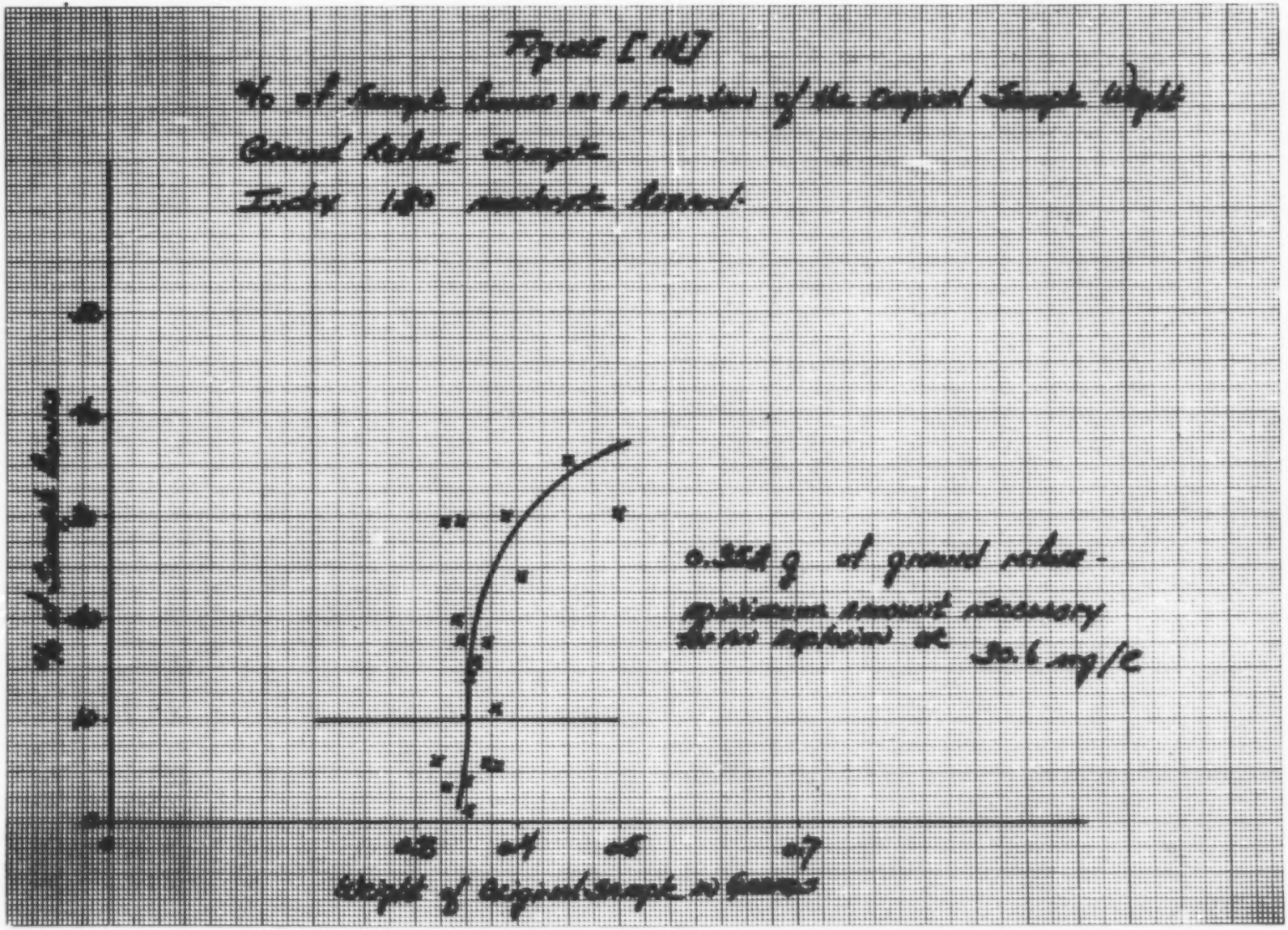


Figure [16]
% of Sample Passing as a Function of the Original Sample Weight
Ground Rubber Sample
Sieve 140 mesh/in. Screen
0.554 g of ground rubber -
Minimum amount necessary
to run system at 30.6 mg/l
% of Sample Passing
Weight of Original Sample in Grams

DISCUSSION

In order to make the data clear to the reader, the explosibility of the dusts was presented as an index. This is a ratio of the minimum explosive concentration of the dust to the minimum explosive concentration of the standard. For example, from Figure (13) the minimum explosive concentration was 0.0306 g/l. Compared to the standard (0.0550/0.0306) a number 1.80 is found and said to be the index. As the index gets larger so does the hazard associated with it, and conversely as the index gets smaller so does the hazard.

The calibration of the dust explosion apparatus was accomplished using a coal dust that the Bureau of Mines employs as their standard. Figures 1 to 5 illustrate four such calibration with the standard.

The data from the calibrations did not lend itself to mathematical study. Figure 5 represents the combination of data from Figures 1 to 4. If a line is drawn through the averages, the resulting graph has two peaks, or 3 minimum explosive concentrations. These minimums are quite close together and were expressed as a range of values rather than an absolute number. In any case, the minimum explosive concentration on our apparatus is in accord with the published minimum explosive concentration and is therefore considered calibrated.

The twin peak aspect of the curve may seem odd, but when compared to other curves, one can see a definite pattern emerging. Figure (15) was the result of working up the ground refuse data in the same manner as the coal dust data. Figure 16 again illustrates the twin peak phenomenon as related to saw dust samples. As the sample weight increased two maximums were observed and 3 minimum

Fig 5-7
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explosive concentrations in a relatively narrow range.

It seems apparent that this effect is common to all the explosive dusts that were studied and could conceivably be attributed to the various sized particles in the sample.

This research was initiated because of an explosion at the Center Hill Incinerator, Cincinnati, Ohio, and its basic goal was to evaluate the explosibility of incinerator dust. Investigations to date have shown that incinerator dust, whether in the air or settled out in some area of the incinerator itself, are not very combustible and do not explode under ordinary situations.

Obviously, since just such an explosion was the reason why this project was undertaken, a discrepancy exists somewhere.

The question of why an explosion could occur was answered by Mr. Nagy of the Bureau of Mines. Samples like incinerator dust are not inherently explosive, but if they reach a high enough concentration and a strong explosive force is supplied, then there is the distinct possibility of an explosion. The explosion at the Center Hill Incinerator seems to fit these conditions quite closely.

Probably the key word associated with dust explosions is dispersion. Without dispersion there can be no explosion. If one can visualize the operation of an incinerator, one can see the movement of tons of refuse in the form of dumping and charging, and it's this movement that stirs up the dust and disperses it in the air. If the area is enclosed, such as the doors being closed, the dust is not allowed to escape, it concentrates. If the dust concentration reaches a high enough level, the addition of some energy, such as

flashback, is all that is necessary to initiate a dust explosion.

Investigation shows us that the Center Hill explosion occurred on a cold dry night when the doors on the incinerator system were closed and the sprinkler system frozen. Dust could easily concentrate in an area like that because of the lack of ventilation and of humidity to keep the dust particles down. It was observed that the explosion appeared to start in the charging hopper, as a flashback, and a flashback from the furnace was all that was needed.

In reality, the elimination of any of those factors (ventilation, humidity, combustible material, or sparks) would be enough to prevent another explosion, but proper ventilation seems like the best way to control the explosion hazard.

Another interesting aspect of this research was the explosibility of ground refuse. Samples of refuse were ground up, ignited, and when compared with the standard, found to have a lower explosive concentration. This means that ground refuse is more than a moderate hazard and care should be exercised in working around grinding operations.

CONCLUSION

Incinerator dusts do not appear to represent the explosive hazard that they were first thought to represent. It should be remembered, however, that an explosion did occur and if certain conditions are maximized; the potential hazard for an explosion is present.

Care should be taken to make sure that incinerators are well ventilated, and dust not allowed to concentrate in places where it could be dispersed.

Ground refuse dusts were found to represent a significant explosive hazard. Care should be taken around these operations to keep dust concentrations to a minimum.

APPENDIX I

Pictures on page 29 illustrate what occurs in a dust explosion. A fine combustible dust is dispersed into the air and ignited by a spark. There occurs a rapid combustion along with the generation of heat and pressure. As long as there is an avenue for this heat and pressure to be released, the explosion is averted. On the other hand, if the area is enclosed, the heat and pressure will build until they exceed the strength of the enclosing material and an explosion results.

There must be proper ventilation when dusty conditions prevail. It will not only lower the dust concentration by dissipating some of the dust, but it will alos provide a safe release for pressure and heat in the event of a dust explosion.

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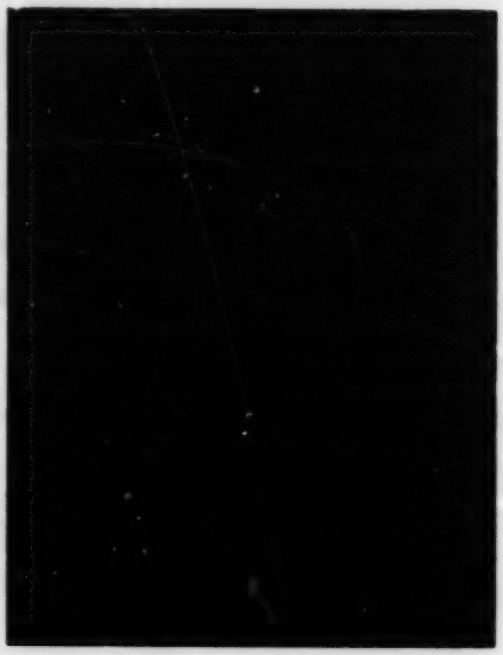

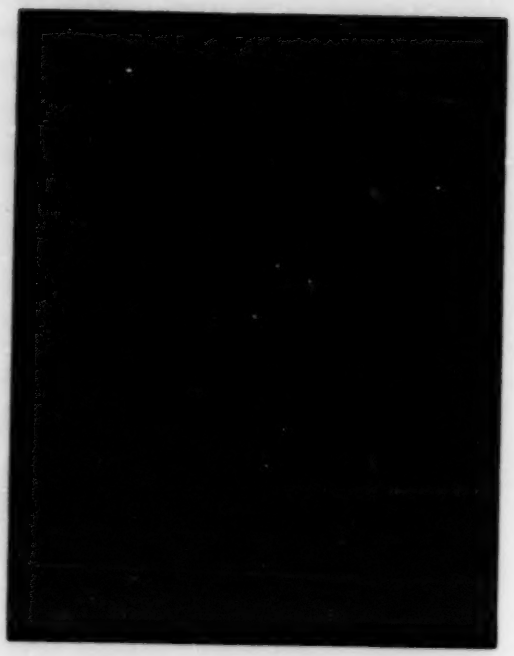

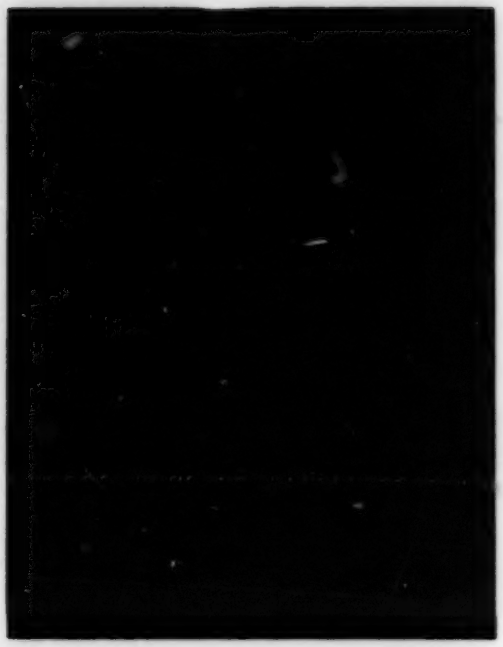

APPENDIX II

Work on the explosibility of incinerator dusts posed several interesting questions. Why should ground refuse explode at lower concentrations than coal dust, and why should incinerator dust not explode at all? These questions should be answered and justified before the collected data can take on any real significance.

In an attempt to answer these questions, a calorific or heat of combustion study was run on the dusts that were studied in the explosion apparatus. It was thought that if the calorific content to be linked to the explosive character, one would have some justification in saying incinerator dust does not explode because its heat of combustion is too low. The data obtained in the calorific study is summarized in Table 1.

APPENDIX III

SAMPLES SENT TO BUREAU OF MINES

As a method of determining how accurate the apparatus developed at Center Hill Laboratories was, several samples were sent to the Bureau of Mines for analysis.

A. Sample #1

Sample #1 was a wall dust sample taken from the Center Hill Incinerator and found to be nonexplosive.

Bureau of Mines test showed a spark ignitible flame in their apparatus but no explosion. They ran their test in the 200 to 2000 mg/l range. They would label such a result as rapid burning rather than an explosion. This type of dust is difficult to make definitive statements, but a past experience has shown that dust of this type can explode if there is a strong igniting force. A flashback from the incinerator could conceivably be such a force and it should be noted as such.

The incinerator dust that was studied by the Bureau of Solid Waste Management and the Bureau of Mines is not explosive unless some special conditions are all present at the same time. Elimination of any one of these will result in the elimination of the explosion hazard.

B. Sample # 2

Sample #2 is a ground refuse sample that was found to be explosive. The Bureau of Mines found the minimum explosive concentration for this sample to be 70 mg/l. Compared with the standard (55 mg/l) it is quite close, and therefore should be considered a

moderate hazard. Appropriate safety steps should then be taken to alleviate the hazard.

Data collected by the Bureau of Mines fit the calorific data better than the Center Hill data. They find the minimum explosive concentration higher than the standard and therefore should have a heat of combustion lower than the standard which in fact it has.

Data from previous Bureau of Mines' work lists paper dust as having an index of 0.8 or 70 mg/l. This fits in quite nicely with the Bureau's value of 70 mg/l for ground refuse.[5]

TABLE 1

CALORIFIC VALUE OF VARIOUS DUSTS

Incinerator	cal/g	Ground Refuse	cal/g	Coal	cal/g
Airborne	3390	Sample #5	3430	Pitts	6667
Charging Floor	2770				
Incinerator Wall	2030				
Platform by Pit	2280				
Railing	2614				

One can see that trying to relate calorific value and the explosive index would be quite a chore. The standard has nearly twice the heat of combustion as the ground refuse, yet the refuse has the larger index. If this were true, then the other incinerator samples should have an index greater than one, but as shown earlier, they do not. This premise does not make sense--the lower the heat of combustion, the more explosive the material. Presently, there is no explanation as to why ground refuse, with a low heat of combustion, is more explosive than the standard, and any prediction on the explosibility of a dust using this method would be erroneous.

A possible answer is that the data taken on the explosibility of ground refuse is incorrect. The Bureau of Mines determined the minimum concentration of ground refuse necessary for an explosion to be 70 mg/l. This is a higher concentration than the standard and fits the calorific data much better.

Whether ground refuse has a minimum explosive concentration of 40 mg/l or 70 mg/l is not the important fact, but that regardless of which concentration it is; ground refuse represents an explosive hazard and should be dealt with as such.

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